REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
3/31/09

2. REPORT TYPE
Final report

3. DATES COVERED *(From - To)*
07/01/2006 - 12/31/2008

4. TITLE AND SUBTITLE
Final Report: Hydrodynamic Design of a Dead Weight Anchor Device Optimized for Station Keeping and Suppression of Subsequent Burial on Sedimentary Beds in Coastal Environments

5a. CONTRACT NUMBER

5b. GRANT NUMBER
N00014-07-1-0382

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)
D'Spain, Gerald L.
Jenkins, Scott

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Marine Physical Laboratory of the Scripps Institution of Oceanography
University of California, San Diego
291 Rosecrans Street
San Diego, California 92106

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
One Liberty Center
875 N. Randolph Street, ONR
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Simulations of station keeping and burial of a dead weight anchor device were performed using the Vortex Lattice Mine Burial/Migration Model (VORTEX). The VORTEX model was developed at Scripps Institution of Oceanography under previous ONR funding, (Inman and Jenkins, 2002; Jenkins and Inman 2002, Jenkins and Wasyl 2006). This model has been validated in field experiments conducted under ONR's Mine Burial Program.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	None	9	Anne J. Footer

19b. TELEPHONE NUMBER *(Include area code)*
858-534-1802

Reset

Final Report: Hydrodynamic Design of a Dead Weight Anchor Device Optimized for Station Keeping and Suppression of Subsequent Burial on Sedimentary Beds in Coastal Environments
ONR Grant # N00014-07-1-0382

Submitted by: Gerald D'Spain and Scott Jenkins
Marine Physical Laboratory
Scripps Institution of Oceanography
291 Rosecrans St.
San Diego, CA 92106

Sponsored by:
Dr. Thomas F. Swean
Office of Naval Research
One Liberty Center
875 N Randolph Street, Suite 1425
Ocean Engineering & Marine Systems (321OE), Rm. 1092
Arlington, VA 22203-1995

1) Model Initialization:

Simulations of station keeping and burial of a dead weight anchor device were performed using the Vortex Lattice Mine Burial/Migration Model (VORTEX). The VORTEX model was developed at Scripps Institution of Oceanography under previous ONR funding, (Inman and Jenkins, 2002; Jenkins and Inman 2002, Jenkins and Wasyl 2006). This model has been validated in field experiments conducted under ONR's Mine Burial Program (Jenkins, et al. 2007).

VORTEX was gridded for an initial canonical shape file provided in SLDASM format (SolidWorks) that was subjected to simulation of station keeping and burial as a function of variation in flow and suspended sediment. Because of the paucity of input data, time series used to specify flow and sediment variability were based on a site surrogate having similar climate, latitude, flow rates, watershed soils and gradients,

Figure 1. Site surrogate, Missouri River at Omaha, NE.

anthropogenic impacts and land use factors. The site surrogate selected for initializing VORTEX simulations was the Missouri River at Omaha, NE (Figure 1). In addition to geophysical similitude, a USGS gage station #06610000 has been maintained on the Missouri at Omaha, NE, since 1928, providing long term flow rate records (Figure 2, black) and significant monitoring of suspended sediment flux (Figure 2, red). A series of dams has been constructed along the upper Missouri River as annotated in Figure 2 and

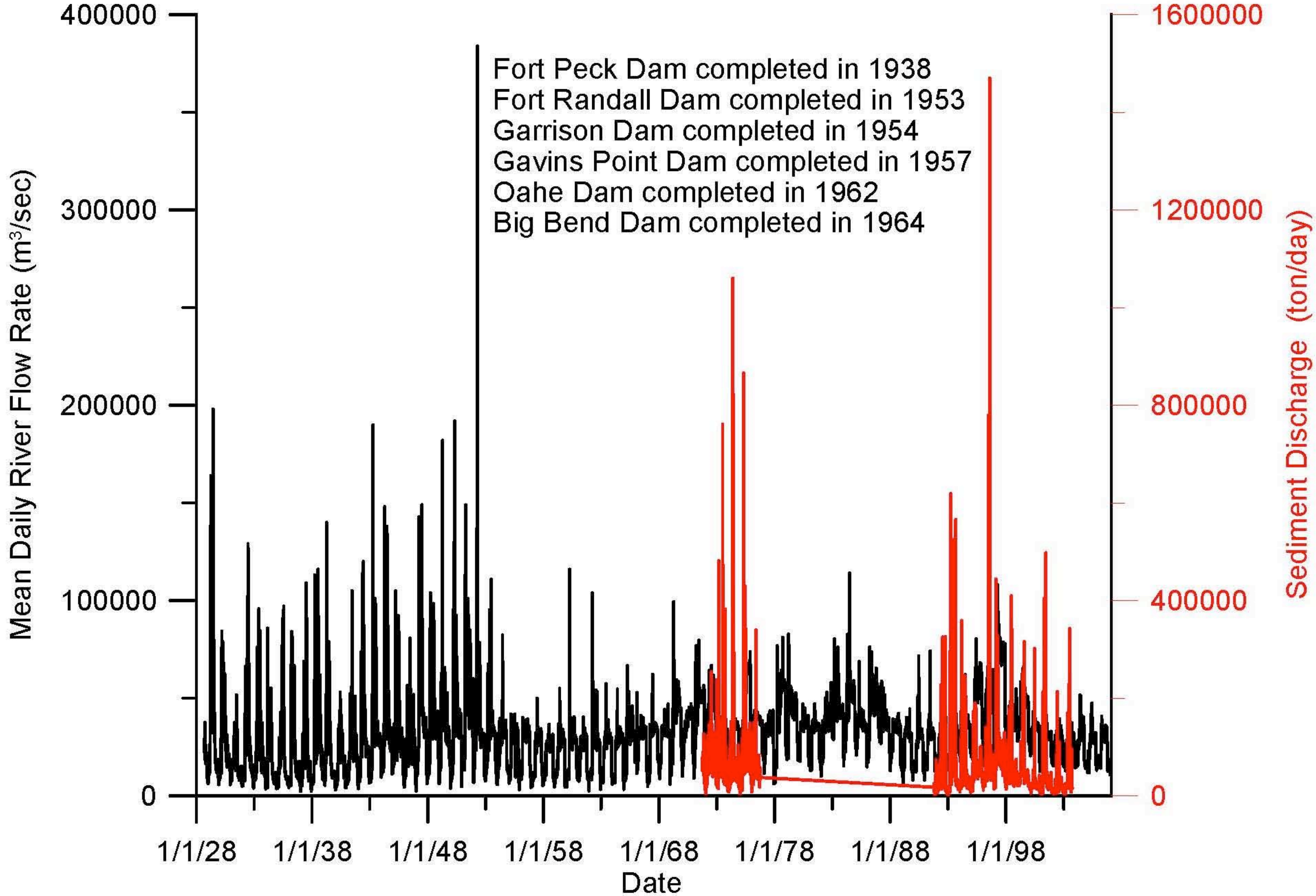

Figure 2: Period of record for USGS gage station # 6610000 - Missouri River at Omaha, NE. Flow rate (black) suspended sediment flux (red).

manipulation of river stage by these dams has limited maximum discharge rates during contemporary periods at Omaha NE to about 40,000 m^3/sec, nearly identical to maximum discharge rates of the prototype environment. Suspended sediment flux data in Figure 2 were convolved into sediment rating curves following the procedure detailed in Inman and Jenkins (1999). Median grain size of the riverbed sediments along the high-speed outboard bank (see red star in Figure 1) of the Missouri at Omaha range from 480 to 520 microns (USGS, 2006). Streambed profiles were used to convert flow rates to local depth integrated velocities at the outboard bank during a 240 simulation period beginning in 1 September 1997 (Figure 3a). This contemporary period was selected for simulation because it provided flow rates exceeding the long term mean, post-dam construction, and could therefore be used as a worst case assessment. During the simulation period, maximum local flow velocities at the point indicated by the star in Figure 1 were $U = 204.5$ cm/sec (3.97 kts) while the minimum was $U = 50.08$ cm/sec (0.97 kts). The mean local flow velocity for the 240 day simulation was $U = 79.84$ cm/sec (1.55 kts). The episodes of high peak velocities in Figure 3a were due to heavy precipitation in the upper Missouri basin associated with upper troughs that entrained unseasonably warm air from lower latitudes. These anomalously warm/wet autumn and early winter weather systems have been attributed to the 1998 El Nino (ENSO) event. Similar anomalous warm/wet events are known to occur in the contemporary prototype environment.

2) Model Simulations:

Figure 3b shows the time evolution of burial of the Bee Hive Concept throughout the simulation period while Figure 4 shows how the Bee Hive migrated downstream during the burial progression. Two basic configurations were studied: the

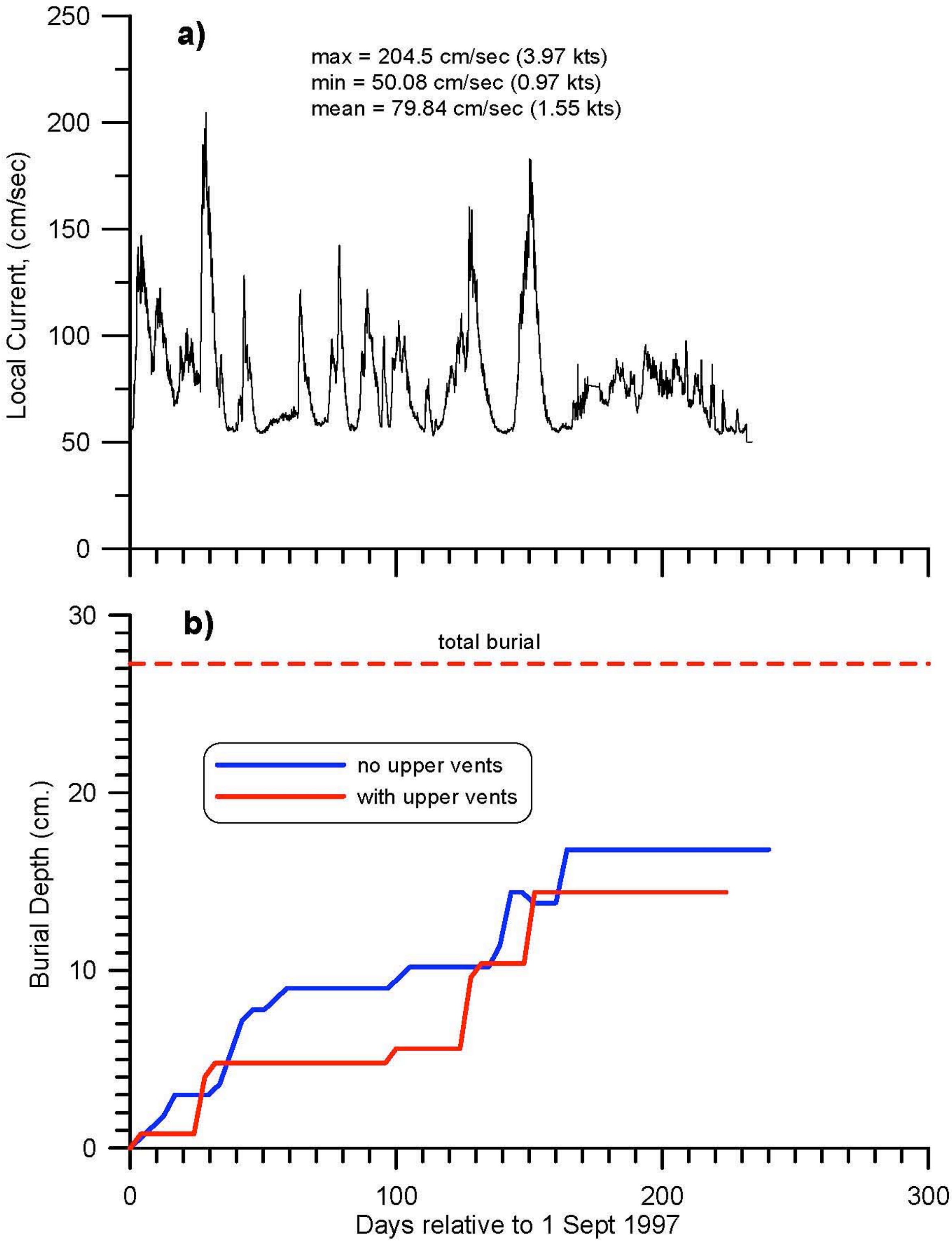

Figure 3: Simulated burial history of dead weight anchor based on proxy hydrograph from Missouri River at Omaha, NE (USGS gage station #06610000). Dry bulk mass = 15.88 kg (dry weight = 35 lb)

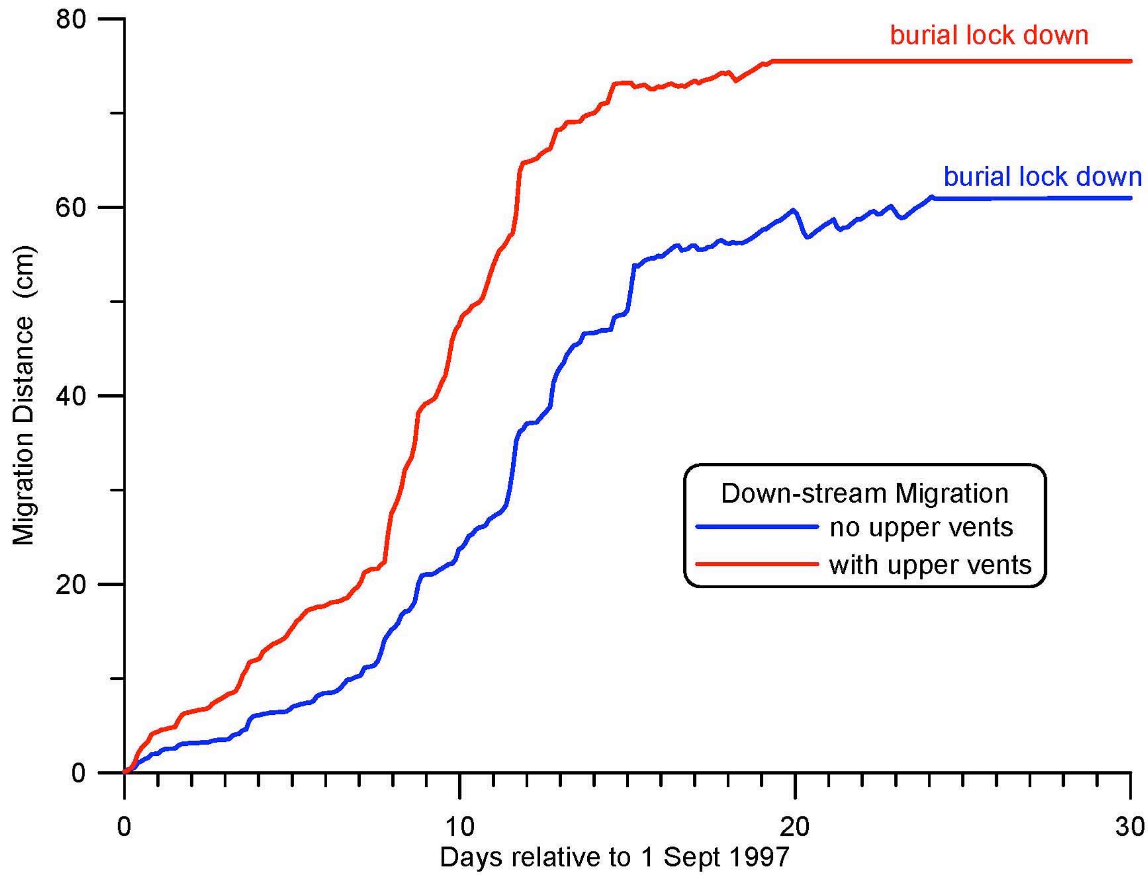

Figure 4: Simulated down-stream migration history of dead weight anchor based on proxy hydrograph from Missouri River at Omaha, NE (USGS gage station #06610000). Dry bulk mass = 15.88 kg (dry weight = 35 lb)

Bee Hive with two pairs of upper vent holes (red); and the Bee Hive without these upper vents (blue). With the upper vents, the Bee Hive buried less but migrated further than without the upper vents. In either case, burial proceeds incrementally with the onset of flow events that exceed about U = 110 cm/sec (2.1 kts). The largest single increment of burial occurs with the peak flow event U = 204.5 cm/sec (3.97 kts), accounting for 32 % of the total burial with the upper vents, and 46% of the total burial without those vents. When the flow speed remains less than 2kts, there is no change in degree of burial. By the end of the simulation, the 14.4 cm of the lower section of the Bee Hive becomes

buried in the river bed sediments when the upper vent holes are present. This burial varies by $\pm$ 8% depending on the orientation of the vent holes relative to the ambient flow, with the smallest degree of burial occurring when the vent holes are aligned on-axis (co-linear) with the flow direction. Without the upper vent holes, the lower 16.8 cm of the Bee Hive becomes buried into the river bed by the end of the 240 day simulation. This degree of burial will require cyclical working or fluidization of the sediment around the Bee Hive in order to extract it from the river bed.

During the first 30 days of the burial progression, the Bee Hive migrates downstream away from its point of initial insertion, until the degree of burial is sufficient to prevent further migration. This arresting of migration is referred to as *burial lock-down*. With the upper vent holes, the Bee Hive achieves lock-down after 19 days following insertion; at which time it will have migrated 75.5 cm downstream of the insertion point. Without the vent holes, the Bee Hive ceases to migrate after 24 days following insertion and will have moved 61 cm downstream of the insertion point.

Flow visualization is helpful in interpreting the burial and migration results. The external streamlines at the threshold burial velocity U = 110 cm/sec (2.1 kts) flowing past the partially buried Bee Hive with upper vents aligned co-linear with the flow. The external streamlines for the same conditions with the vent holes aligned normal to the flow; contrast with results with no vent holes. Inspection of the wake in the region of the downstream scour depression of these three examples reveals that the configuration with flow co-linear vent holes produces the least amount of vortical motion in the wake; and that the no-vent configuration produces the most intense and well developed vortices in the wake region. Jenkins et al (2007) show that burial rate increases with the intensity of

the wake vortices since these provide the primary mechanism for eroding and excavating the bed in the immediate neighborhood of the body. In other words, the pass-through flow provided by the co-linear vent holes ventilates the wake and suppresses vortex roll in the nearfield scour region. The pass-through flow and wake ventilation is less effective when the vent hole are aligned flow-normal and consequently wake vortex roll-up is better developed and burial increases by 8 %. Without any wake ventilation in the absence of vent holes the wake vortices are fully developed and burial is 17 % greater than the flow co-linear vent hole configuration.

The wake ventilation provided by the vent holes comes at a price. A very complex vortex system are formed inside the Bee Hive that manifests itself as *internal drag* , and represents an additional drag constituent that the no-vent configuration does not have. The internal drag of the vented Bee Hives contributes to a higher total drag that in turn, causes more migration during the initial post-insertion phase before burial lock-down ensues. However this conclusion may be an artifact of the absence of information about what’s inside the Bee Hive. The well developed internal vortices of the vented Bee Hives are made possible by the large internal void space in the model. If the vent holes terminate in internal plumbing and capacity bottles, than these internal vortices do not develop, and conditions inside the Bee Hive are closer to stagnation; whence internal drag is not produced. For that matter, the ventilation of the wake modeled in Figure 5 may be an artifact of a pass-through flow that never actually develops due to internal obstructions. In that case the un-vented model results (blue lines in Figures 3 and 4) may be a better representation of the actual performance of the Bee Hive device.

References:

Inman, D. L. & S. A. Jenkins, 1999, “Climate change and the episodicity of sediment flux of small California rivers,” *Jour. Geology,* v. 107, p. 251–270.

Inman, D. L. and S. A. Jenkins, 2005, “Scour and Burial of Objects in Shallow Water,” in *Encyclopedia of Coastal Science*, M. Schwartz, Ed. Dordrecht, Netherlands: Kluwer Academic Publishers, 2005, pp. 1020–1026.

Inman, D. L. and S. A. Jenkins, 2002 “Scour and Burial of Bottom Mines, A Primer for Fleet Use,” Scripps Institution of Oceanography: Univ. of California, San Diego, SIO Reference Series 02-8, 2002. Available: http://repositories.cdlib.org/sio/reference/02-8/

Jenkins, S. A. and D. L. Inman, 2002, “Model for Mine Scour and Burial: An Illustrated Abstract with Technical Appendix,” Scripps Institution of Oceanography: University of California, San Diego, SIO Reference Series 02-2, 2002.

Jenkins S. A., & D. L. Inman, 1985, “On a submerged sphere in a viscous fluid excited by small amplitude periodic motions,” *Jour. Fluid Mech.*, v. 157, pp. 199-224.

Jenkins S.A. & D. L. Inman, 14 Sept. 2000, “Numerical Modeling of Station Keeping for the VSW/MCM Neutralization Marker,” technical report submitted Code D352 SPAWAR, San Diego, CA, 6 pp., 10 figs.

Jenkins S. A. and D. L. Inman, 2006, “Thermodynamic solutions for equilibrium beach profiles,” *J. of Geophysical Res.*, vol. 111, C02003, doi:10.1029/2005JC002899, 21 pp., 2006.

Jenkins, S. A., Inman, D.L., Michael D. Richardson, M.D., Thomas F. Wever, T.F. and J. Wasyl, 2007, “Scour and burial mechanics of objects in the nearshore”, *IEEE Jour.Oc.Eng*, vol. 32, No. 1, pp 51-65.

USGS, 2006, *National Water Information System*: http://waterdata.usgs.gov/nwis/dv/?site_no=06610000&referred_module=sw